Reports of the Department of Geodetic Science

Report No. 71

PROPOSED OPTICAL NETWORK FOR THE NATIONAL GEODETIC SATELLITE PROGRAM

by

Ivan I. Mueller

Prepared for

National Aeronautics and Space Administration
Washington, D.C.

Contract No. NSR 36-008-~~003~~ 033

The Ohio State University
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PREFACE

The execution of this research is under the technical direction of the Director, Physics and Astronomy Programs, and of the Project Manager of the National Geodetic Satellite Program, both at NASA Headquarters, Washington, D.C. The contract is administered by the Office of Grants and Research Contracts, Office of Space and Science and Applications, NASA, Washington, D.C.

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The Ohio State University has been requested by the National Aeronautics and Space Administration to conduct a multi-year study and analysis of data from satellites launched specifically for geodetic purposes and from other satellites useful in geodetic studies. The program includes analysis of positions derived from photographic observations of both reflecting and emitting satellites, from range observations and from any other suitable but similar types of data. The final result is supposed to be a geocentric-geodetic datum for the whole earth with connections to all major datums and NASA supported stations.

Planning an observational network, in accordance with the goals mentioned above, starts with a review of certain factors which can not or should not be ignored. Such factors are the following:

1. The existing geodetic datums. Figure 1 shows a map of the world with numbers indicating the various datums which have been used by the different countries. There have been about 90 different datums in use which are listed in Table 1and by countries in Table 2. Since some countries are on the same geodetic datum and since some datums are tied together with ground survey (see Figure 2), it is possible to combine the 90 datums into about 20 large or independent datum-blocks. Figure 3 shows these blocks of datums. One purpose of this satellite program is to combine these datum-blocks into one common system.

2. The USCGS-DOD satellite triangulation network. Figure 4 shows this network as proposed, together with collocated TRANET, SAO, and SECOR

stations. Some other stations are also shown which are significant from the point of view of this proposal. The stations of the USCGS-DOD network are listed in Tables 3 and 4. The collocated stations are tabulated in Table 5.

3. The NASA supported tracking stations. These are the Manned Space Flight Network, the Apollo Unified S Band Network, the Satellite Tracking and Data Acquisition Network (STADAN), the Smithsonian Optical Network, and the Deep Space Instrumentation Facilities (Table 6 and Figure 5).

The most feasible approach to take seems to first establish relative ties between the NASA stations and the planned USCGS-DOD or SAO networks. These in turn are tied to "absolute" stations, where satellite observations are available for a long period of time (e.g., six SAO and six TRANET stations). All these ties could be accomplished by means of the simultaneous mode. Using data collected through many months at the absolute stations, all coordinates could then be transformed to a geocentric-inertial system.

Going back to the relative ties, only those NASA tracking stations are proposed to be tied by means of satellites whose relative positions with respect to the USCGS-DOD or SAO stations can not be determined accurately through existing ground surveys. The criterion used for the elimination of some NASA stations is that the length of the existing ground survey (e.g., triangulation-chain) between the station and the nearest USCGS-DOD or SAO station should not exceed 1,000 km. This figure was arrived at by requiring a ± 10 m relative accuracy for the stations with respect to the nearest USCGS-DOD or SAO site, and assuming an average 1:100,000 proportional accuracy for the existing ground surveys. In addition to this, it is also checked whether each independent datum-block shown

in Figure 3 has at least one station (in the larger blocks two stations) in it. If no station is found, a new one is added at a suitable location.

Figure 6 and Table 7 show the proposed network, supplementary to the one planned by the USCGS-DOD. Stations which need to be set up, or where additional instrumentation to the existing facilities is needed, are denoted by N. The numbers in parentheses indicate the type of camera suggested. The number (1) indicates cameras of the type MOTS, PC-1000, or similar, which are capable to observe only the flashing GEOS satellites, while the number (6) indicates BC-4 or similar cameras capable of chopping the trail of passive satellites (e.g., PAGEOS). The same numbers on the ties suggest the type of cameras used at the terminal points. The lines with (1) are shorter than those with (6) due to the different expected altitudes of the satellites mentioned. It can be seen that by adding eleven BC-4 or similar stations and 23 MOTS or similar stations to the presently planned USCGS-DOD and SAO networks, the geometric goals envisioned for this part of the National Geodetic Satellite Program may be accomplished.

The scale necessary in the computations could be obtained by either using the SECOR stations collocated with the BC-4 stations as shown in Figure 4, or by utilizing some extended precise base lines measured on the ground, or laser tracking.

Figure 7 shows the complete geometric-system with the datum-blocks, USCGS-DOD, SAO, and the new network. The approximate number of observations required for the various networks are indicated in Table 8.

It should be mentioned also that DOD plans, other than those mentioned, were not incorporated in this proposal since it can not be determined at this

time when data obtained through these facilities will be made available to the scientific community. The DOD observational plan is shown on Figure 8 with station locations tabulated in Tables 9 - 13. This plan is supplementary to the USCGS-DOD plan shown in Figure 4.

The proposed network, if adopted, will be used first in a detailed simulation study to find out what accuracies can be expected in the given geometrical situation. It is possible that this study might require some minor modifications of the plan.

TABLE 1
LIST OF PRINCIPAL GEODETIC DATUMS

Map Designation Number	Datum Name[1]	Ellipsoid[3]	Origin	Country[2]
1	North American 1927	Clarke 1866	Meades Ranch, Kansas	Bermuda, Brazil*, British Guiana*, British Honduras, Canada, Costa Rica, Cuba, Dominican Republic, El Salvador, French Guiana*, Iceland*, Guatemala, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Surinam*, United States of America, Venezuela*
2	European 1950	International	Potsdam, Germany	Continental Europe*, Iran*, Iraq*, Israel*, Jordan, Lebanon*, North Africa*, Syria*, Turkey*
3	South American	International	La Canoa, Venezuela	Brazil*, British Guiana*, Bolivia, Chile, Colombia, Ecuador, French Guiana*, Peru, Surinam*, Venezuela*
4	Argentinean	International	S. E. end of Castelli Base	Argentina
5	Indian	Everest	Kalianpur	Afghanistan, Burma, Cambodia*, Ceylon, India, Laos*, Nepal, North Vietnam*, Pakistan, South Vietnam*, Thailand
6	Tokyo	Bessel	Tokyo Observatory	Japan, Korea, Manchuria*, Philippines*

TABLE 1 (continued)

Map Designation Number	Datum Name[1]	Ellipsoid	Origin	Country[2]
7	Australian	Kaula	Grunby	Australia, Papua
8	Pulkovo 42	Krasovsky	Pulkovo Observatory	Bulgaria*, Czechoslovakia*, Estonia*, Hungary*, Latvia*, Poland*, Rumania*, Union of Soviet Socialist Republic*
9	Cape	Clarke 1880	Buffelsfontein	Basutoland, Bechuanaland, Kenya*, Mozambique*, Rwanda-Burundi*, South Africa, Southern Rhodesia, South West Africa, Swaziland, Tanzania*, Uganda*
10	New British	Airy	Greenwich Observatory	Great Britain*, Ireland
11	New French	Hayford	Paris Observatory	Belgium*, France*
12	Belgium 1950	Hayford	Lommel Signal	Belgium*, Luxembourg*
13	Amersfoort 1885	International	Amersfoort I	Netherlands*
14	Portugal	Clarke 1880 Bessel	San Jorge Observatory	Portugal*
15	Madrid 1958	Struve	Madrid Observatory	Spain*
16	New Rome 1940	Bessel	Monte Mario	Italy*, Sicily*, Corsica*, Sardinia*
17	Albanian	Bessel	Tirana-Durazza Highway	Albania*
18	Swiss	Bessel	Bern	Switzerland
19	New Bulgarian	International	Tscherni Wrch	Bulgaria*

TABLE 1 (continued)

Map Designation Number	Datum Name[1]	Ellipsoid[3]	Origin	Country[2]
20	Cyprus		Famagusta	Cyprus
21	Greek	Bessel	Athens Observatory	Greece*, Crete*
22	New Rumanian	Bessel	Military Observatory Bucharest	Rumania*
23	Austrian	Bessel	Hermanskogel	Austria*, Czechoslovakia*, Yugoslavia*
24	German	Bessel	Potsdam, Helmertturm	Austria*, Czechoslovakia*, Germany*, Poland*
25	Vienna University System	Bessel		Austria*
26	New Hungarian	Bessel	Gellerthegy	Hungary*, Rumania*
27	St. Anna System	Bessel		Czechoslovakia*
28	Danish	Danish, Hayford	Agri Bavehole	Denmark*
29	Helsinki	Hayford	Helsinki (Kallio Church)	Finland*
30	Gellerthegy 1908	Bessel	Gellerthegy	Poland*
31	Iceland	Danish	Reykjavik	Iceland*
32	Norwegian	Bessel	Oslo Observatory	Norway*
33	Swedish-Russian	Bessel	Depot Point and Point Thumb converted to Green Harbor	Spitzbergen
34	Stockholm	Bessel	Stockholm Observatory	Sweden*
35	Egyptian 1930	Helmert 1907	Venus Station	Egypt*

TABLE 1 (continued)

Map Designation Number	Datum Name[1]	Ellipsoid[3]	Origin	Country[2]
36	Blue Nile	Clarke 1880	Station 15, Adindan Baseline, 30th meridian	Ethiopia, Sudan
37	New Arc 1950	Clarke 1880	Campos Rodregues Observatory	Kenya*, Mozambique*, Tanzania*, Uganda
38	Angola	Clarke 1866	Camp de Aviaco	Angola
39	Oriental Province	Clarke 1880	Station Igura, 30th meridian arc	Republic of Congo (Leopoldville) Rwanda-Burundi*
40	Lower (Bas) Congo	Clarke 1880		Republic of Congo (Brazzaville)
41	Ghana	War Office	Legion	Ghana
42	Reguliere	Clarke 1880	Merchich	Morocco*
43	Algerian	Clarke 1880	Colonne Voirol	Algeria*
44	Tunisian	Clarke 1880	Carthage	Tunisia*
45	Guinean	Clarke 1880	Conakary	Guinea, Ivory Coast
46	Nigerian	Clarke 1880	Minna	Nigeria
47	Portuguese Guinean	International	Bissau	Portuguese Guinea
48	Sao Tome	Clarke 1880	Sao Tome	Sao Tome
49	Senegal	Clarke 1880	Dakar, Saint Louis	Senegal
50	CNG Provisional	International	Corrego Alegre	Brazil*, Paraguay
51		International	Cerro de Montevideo	Uruguay*
52	Hanoi	Clarke 1880	Hanoi Belvedere	Cambodia*, Laos*, North Vietnam*, South Vietnam
53	Taiwan	Bessel	Hu-tzu-shan	Taiwan

TABLE 1 (continued)

Map Designation Number	Datum Name[1]	Ellipsoid[3]	Origin	Country
54	Hong Kong	Clarke 1880	Royal Observatory Kau Lung	Hong Kong
55	Pescadores	International	Kobokutei	Pescadores
56	Manchurian Principal	Bessel	Shinkyo (Hsin-ching)	Manchuria*
57	Chatham 1950	Everest	Observatory of Chatham Islands	Andaman Islands
58	Camorta	Everest	Camorta Observatory	Nicobar Islands
59	Malayan Revised	Everest	Kertau	Malaysia
60	Luzon	Clarke 1880	Balanacan	Philippines*
61	West Chinese	International	Kweiyang	China
62	East Chinese	International	Nanking	China
63	Red Bridge		Red Bridge (Hopeh)	China
64	Peiping System 1954	Krasovsky	Peiping	China
65	Sumatra-Java	Bessel	Batavia (Genoek)	Indonesia
66	Borneo	Bessel	G. Segara	Indonesia
67	Bangka	Bessel	Bukit Rimpah	Indonesia
68	South Celebes	Bessel	Montjang Lowe	Indonesia
70	North Celebes	Bessel	Wenanghill (P 56)	Indonesia
71	Saudi Arabian	Several isolated datums		Saudi Arabia

TABLE 1 (continued)

Map Designation Number	Datum Name[1]	Ellipsoid[3]	Origin	Country[2]
72	Trucial Coast	Several isolated datums		Trucial Coast
73	Nahrwan	Clarke 1880	Nahrwan	Iran*, Iraq*, Lebanon*, Syria*
74	Palestine	Clarke 1880	Imaya Base	Israel*
75	Turkish	International	Istanbul	Turkey*
76	Old Hawaiian	Clarke 1866	Oahu West Base	Hawaii
77	Ascension Island 1958	International	(Mean of 3 stations)	Ascension Island
78	Pico de las Nieves	International	Pico de las Nieves	Canary Islands
79	El Aaium	International	El Aaium	Spanish Sahara
80	Gambia	Clarke 1858	East Base	Gambia
81	Sierra Leone	Clarke 1880	Astro Pos. of SLX2	Sierra Leone
82	Conakary (Guinea)	Clarke 1880	Railway Astro Pillar	Upper Volta, Mali
83	Minna	Clarke 1880	Minna Base (N. Term)	Cameroon
84	Massaua	Bessel	Massaua	Eritrea Province, Ethiopia
85	Aden	Clarke 1880	Aden Observatory	Aden
86	Nahrwan	Clarke 1880	Nahrwan (S. E. Base)	Kuwait, Saudi Arabia, Qatar
87	Timbalai	Everest	Timbalai	North Borneo, Sarawak
88	Papataki	International	Papataki	New Zealand
89	Puerto Rico	Clarke 1866	Cardona Island	Puerto Rico*

[1] The name of the datum is either the accepted usage or the name of the country where used.

[2] Asterisk denotes that the country (or part of it) is on more than one datum.

[3] Parameters of reference ellipsoids listed are as follows:

Name	a_e	1/f
Airy	6,377,563.396 m	299.324964
Bessel	6,377,397.155	299.152813
Clarke 1866[a]	6,378,206.4	294.978698
Clarke (modified) 1880	6,378,249.145	293.4663
Everest	6,377,276.345	300.8017
Hayford 1906	6,378,283	297.8
Hayford (International Ellipsoid)	6,378,388	297.0
Helmert 1907	6,378,200	298.3
Kaula[b]	6,378,160	298.25
Krasovsky[c]	6,378,245	298.3
War Office	6,378,306.1	296.0

[a] Defined by the values of a_e and b_e = 6,356,583.6 m

[b] Recommended by the International Astronomical Union, 1964

[c] Originally a triaxial ellipsoid (equatorial ellipticity = 1/30,000; direction of the longest axis, λ = 15° E)

COUNTRIES WITH GEODETIC

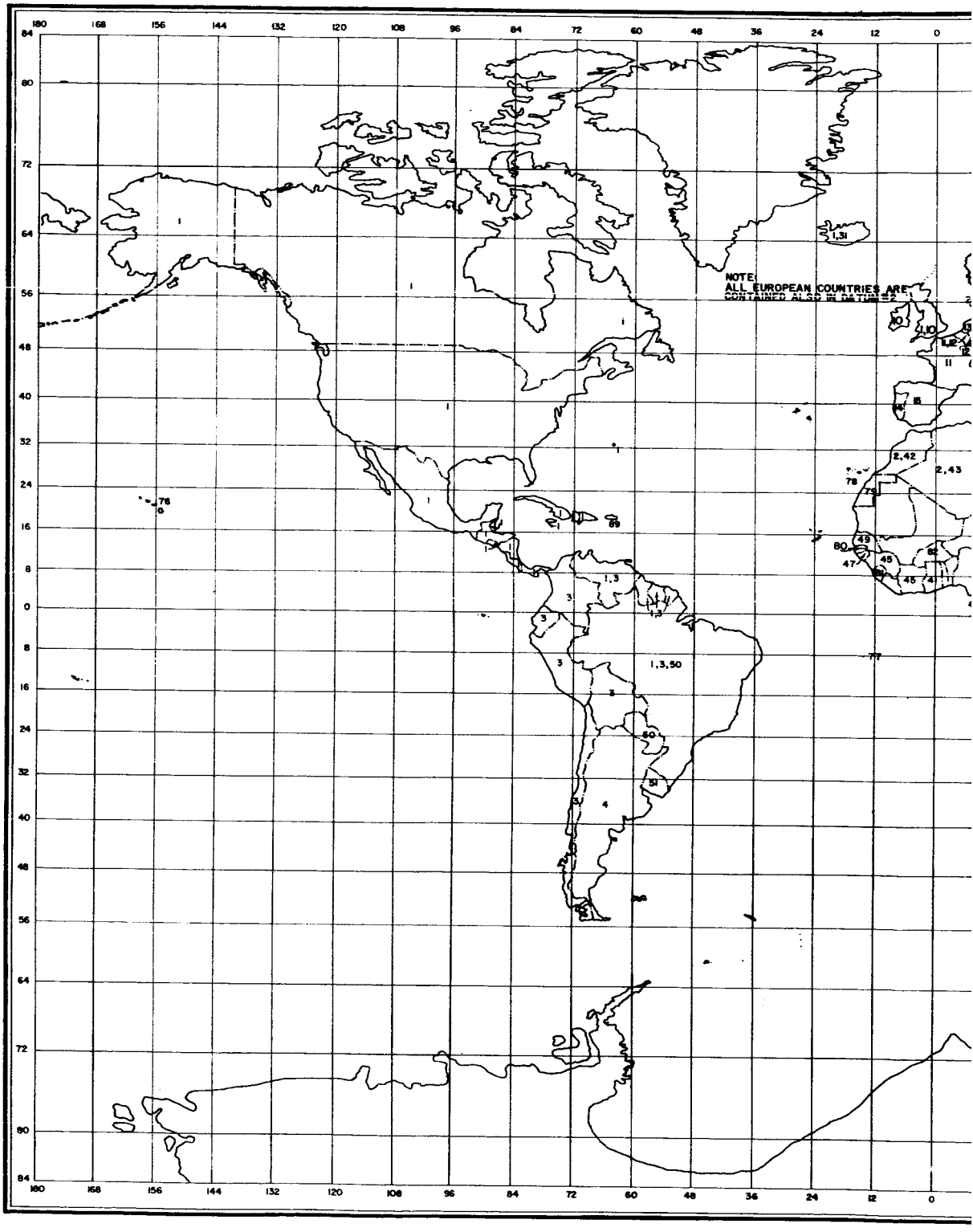
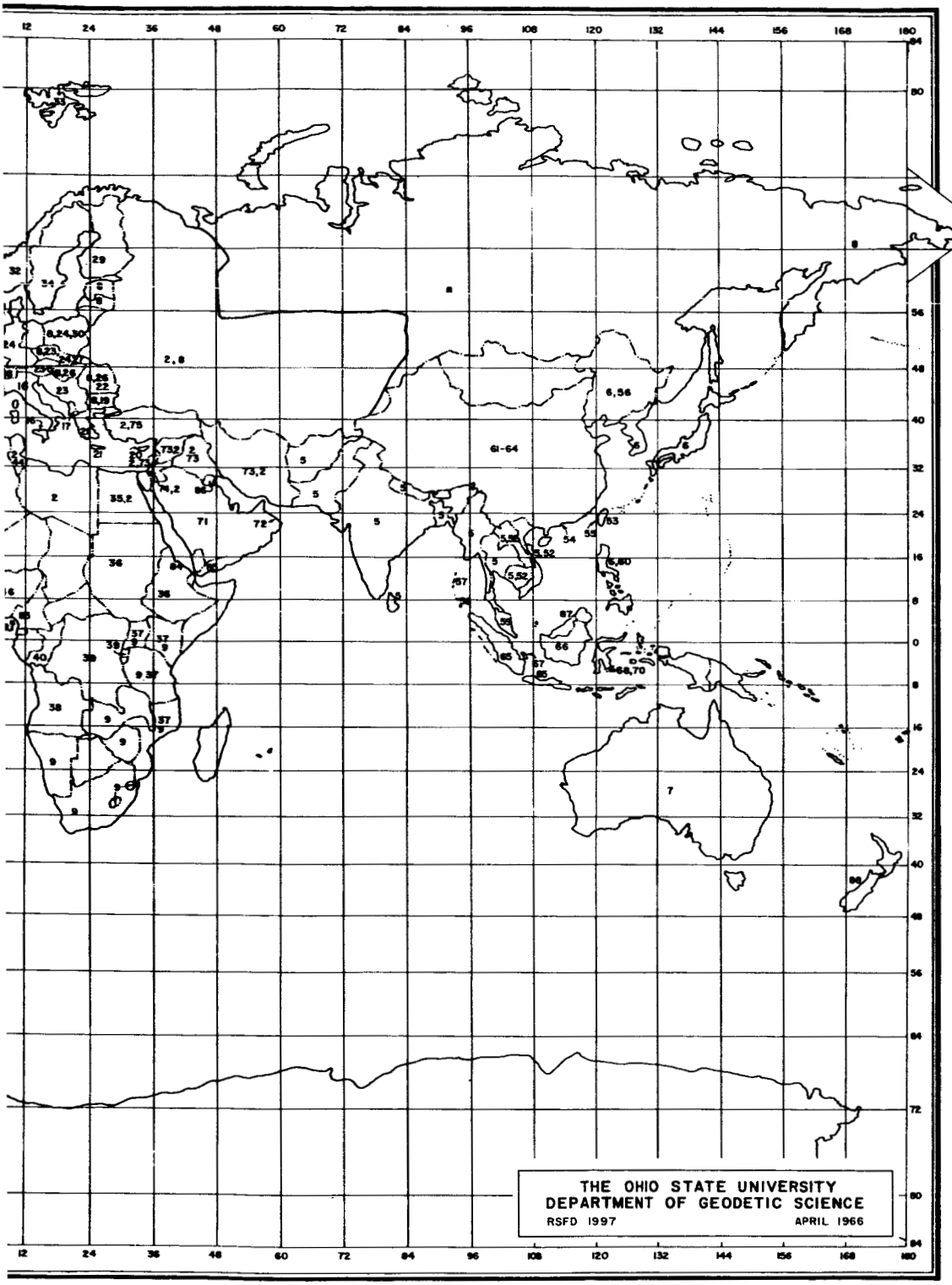


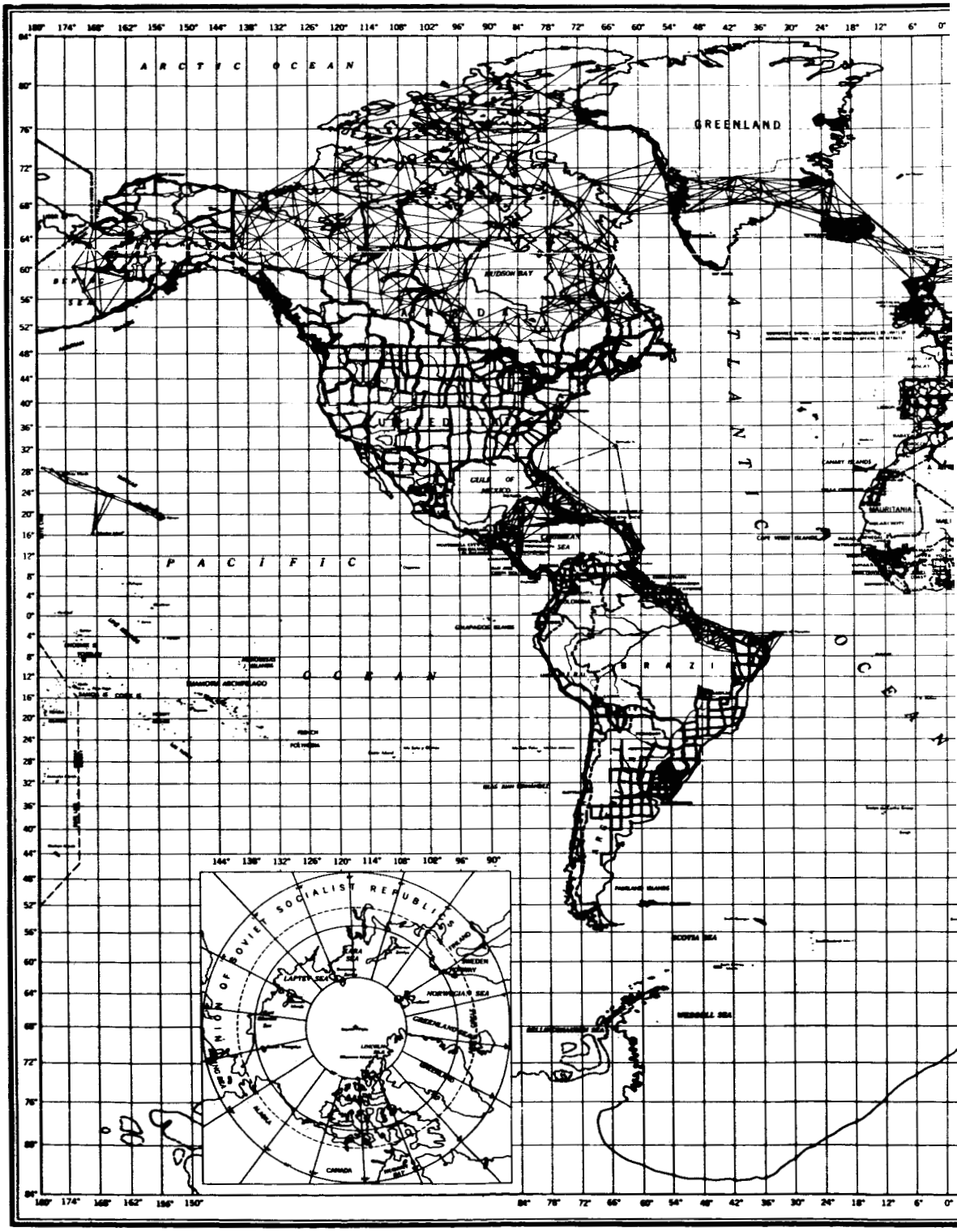
Figure 1

DATUM DESIGNATIONS



F.1-2

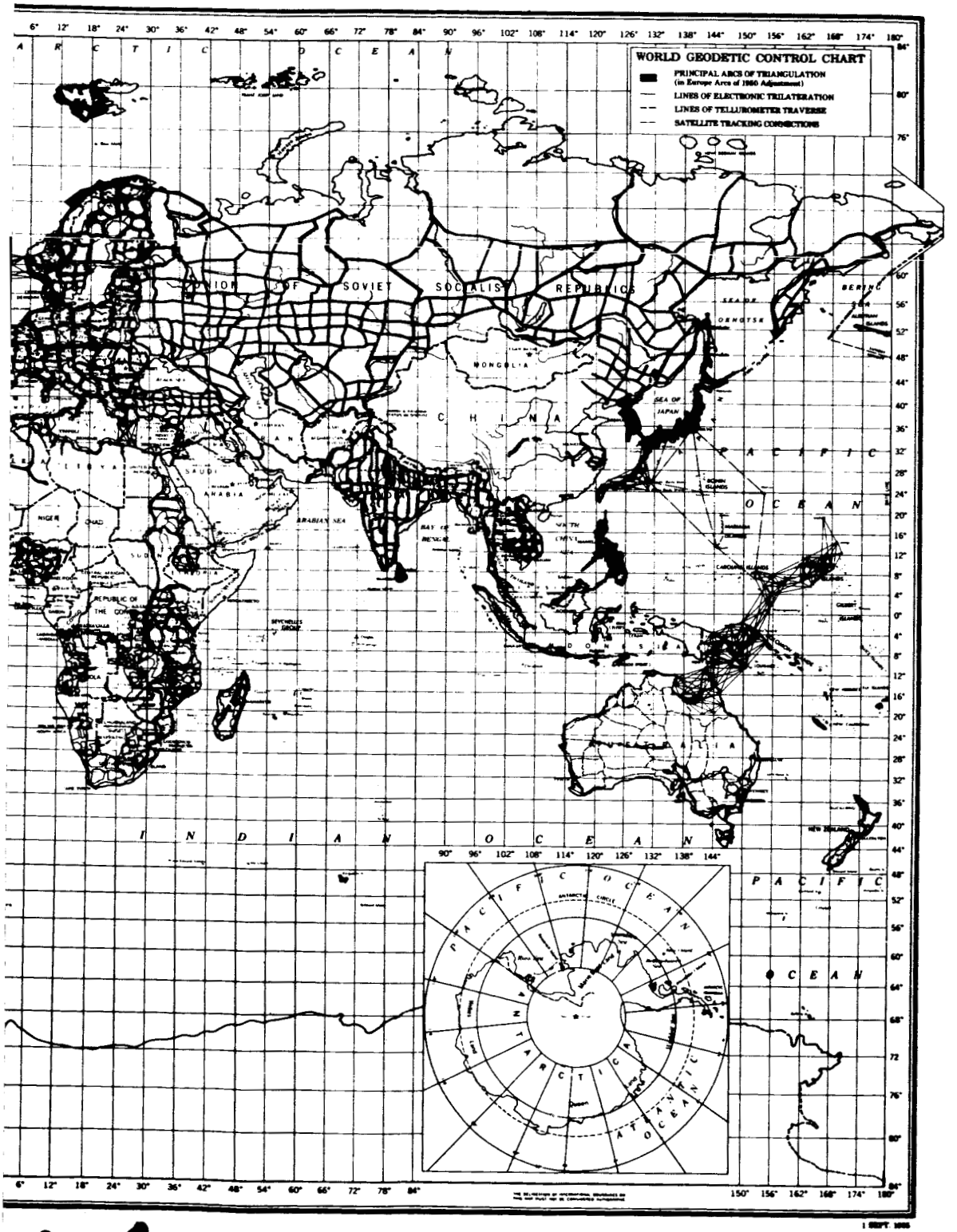
FUNDAMENTAL GEODETIC NET



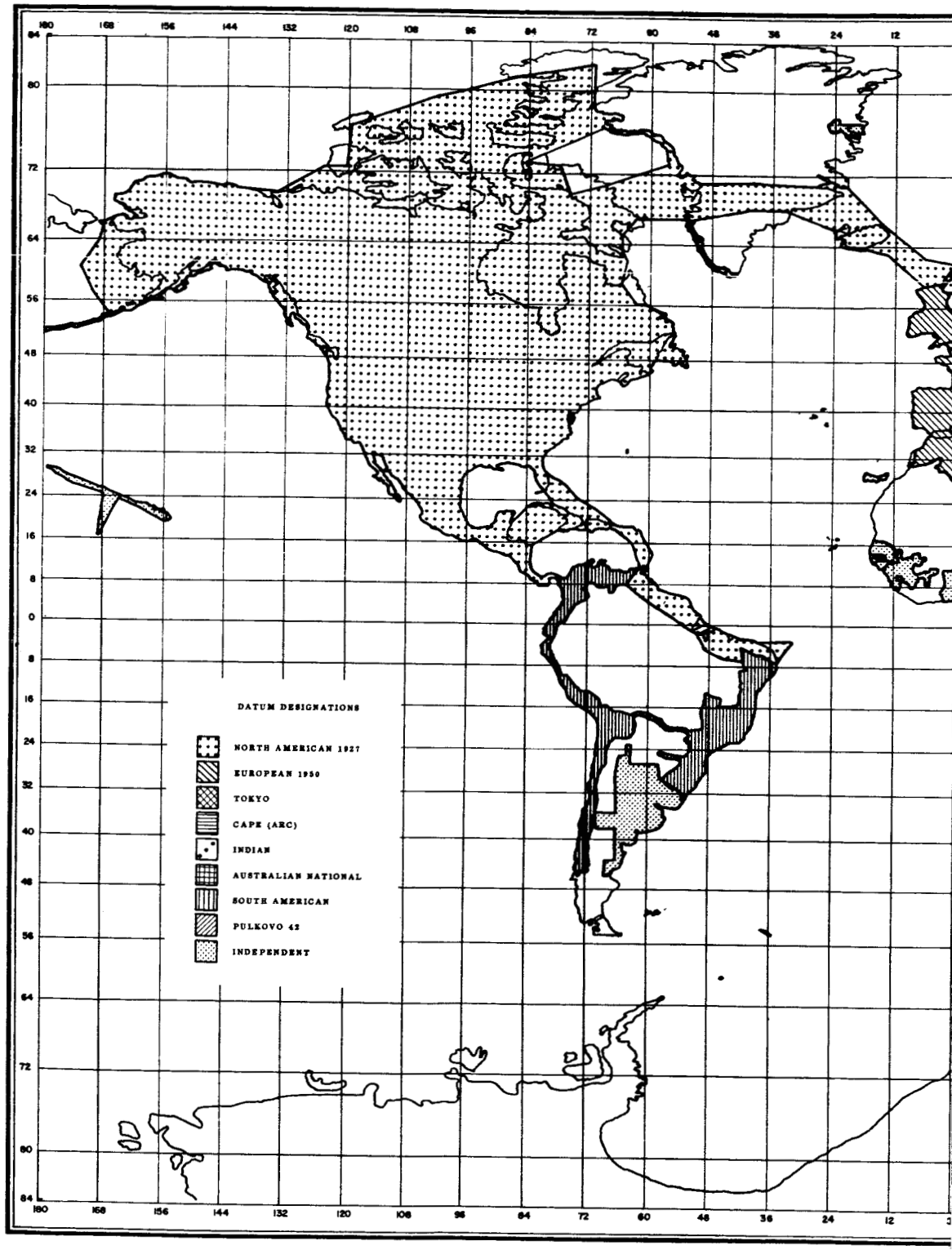
Figur

Fig 2-1

WORKS (HORIZONTAL CONTROL)



MAJOR GEODETIC



Figur

3-1

DATUM BLOCKS

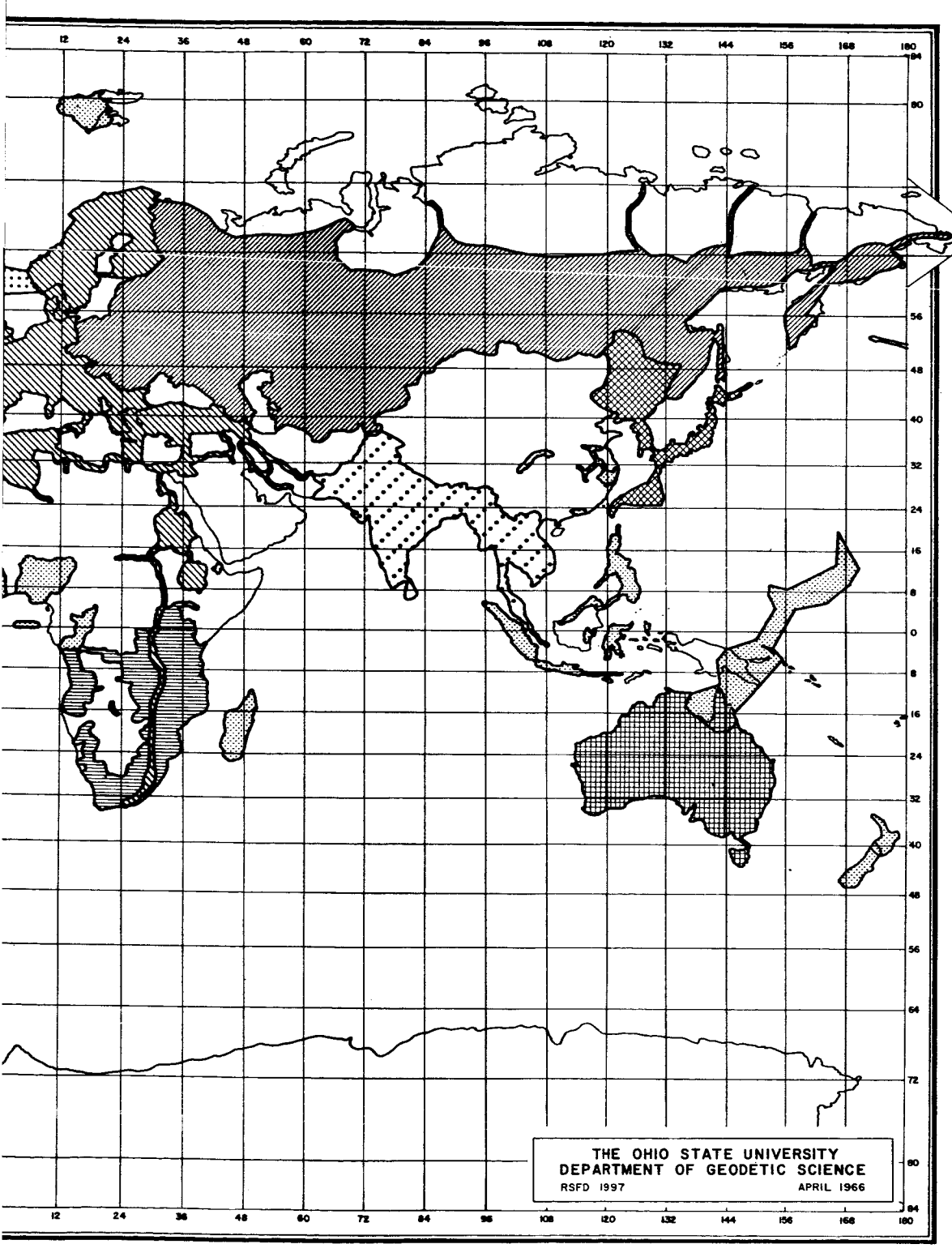


TABLE 2
LIST OF COUNTRIES WITH DATUM DESIGNATIONS*

Continent	Country	Datum Designation*
Africa	Algeria	43,2
	Angola	38
	Basutoland	9
	Bechuanaland	9
	Cameroon	83
	Canary Islands	78
	Chad	
	Central African Republic	
	Dahomey	
	Egypt	35,2
	Eritrea	84
	Ethiopia	36
	French Somali-Land	
	Gabon	
	Gambia	80
	Ghana	41
	Guinea	45
	Ivory Coast	45
	Kenya	37
	Liberia	
	Libya	2
	Malagasy	
	Mali Federation	82
	Mauritania	
	Morocco	42,2
	Mozambique	37
	Nigeria	46
	Portuguese Guinea	47
	Republic of the Congo (Brazzaville)	40
	Republic of the Congo (Leopoldville)	39
	Rio Muni	
	Rwanda-Burundi	9,39
	Sao Tomé	48
	Senegal	49

*Blank space indicates that there is no information available on the geodetic datum used. Numbers refer to Table 1.

TABLE 2 (continued)

Continent	Country	Datum Designation
Africa	Sierra Leone	81
	Somali Republic	
	South Africa	9
	Southern Rhodesia	9
	South-West Africa	9
	Spanish Sahara	79
	Sudan	36
	Swaziland	9
	Tanzania	37
	Togo	
	Tunesia	44,2
	Uganda	37,39
	Upper Volta	82
	Aden	85
Asia	Afghanistan	5
	Andaman	57
	Borneo	66,87
	Burma	5
	Cambodia	5,52
	Celebes	70
	China	61,62,63,64
	Ceylon	5
	Hong Kong	54
	India	5
	Iran	73,2
	Iraq	73,2
	Israel	74,2
	Japan	6
	Jordan	2,74
	Korea	6
	Kuwait	86
	Laos	5,52
	Lebanon	73,2
	Malaya	59
	Manchuria	6,56
	Mongolia	
	Nepal	5
	New Guinea	
	Nicobar Islands	58
	North Borneo	
	North Vietnam	5,52

TABLE 2 (continued)

Continent	Country	Datum Designation
Asia	Pakistan	5
	Pescadores	55
	Philippines	6, 60
	Qatar	86
	Sarawak	87
	Saudi Arabia	71, 86
	South Vietnam	5, 52
	Sumatra	65
	Syria	73, 2
	Taiwan	53
	Thailand	5
	Trucial Coast	72
	Turkey	75, 2
	Union of Soviet Socialist Republic	8
	Yemen	
Australia	Australia	7
	New Zealand	88
	Papua	7
Europe	Albania	12, 2
	Austria	22, 24, 25, 2
	Belgium	11, 12, 2
	Bulgaria	19, 2
	Corsica	16, 2
	Cyprus	20, 2
	Czechoslovakia	23, 24, 27, 2
	Denmark	28, 2
	Estonia	88, 22
	Finland	29, 2
	France	11, 2
	Germany	24, 2
	Great Britain	10
	Greece and Crete	21, 2
	Hungary	26, 2
	Ireland	10
	Italy and Sicily	16, 2
	Latvia	8, 2
	Luxembourg	12, 2
	Netherlands	13, 2
	Norway	32, 2
	Poland	30, 2
	Portugal	14, 2

TABLE 2 (continued)

Continent	Country	Datum Designation
Europe	Rumania	22, 26, 21, 2
	Sardinia	16, 2
	Spain	15, 2
	Spitsbergen	33, 2
	Sweden	30, 2
	Switzerland	18, 2
	Turkey	2
	Union of Soviet Socialist Republic (European part)	8, 2
	Yugoslavia	23, 2
North and South America	Argentina	4
	Ascension Island	77
	Bermuda Islands	1
	Brazil	3, 50
	British Guiana	3
	British Honduras	1
	Bolivia	3
	Canada	1
	Chile	3
	Colombia	3
	Costa Rica	1
	Cuba	1
	Dominican Republic	1
	Ecuador	3
	El Salvador	1
	French Guiana	3
	Guatemala	1
	Greenland	
	Haiti	1
	Hawaii	76
	Honduras	1
	Iceland	31
	Jamaica	1
	Mexico	1
	Nicaragua	1
	Panama	1
	Paraguay	50
	Peru	3
	Puerto Rico	1, 89
	Surinam	3
	United States of America	1
	Uruguay	51
	Venezuela	3

TABLE 3
USCGS-DOD PRIMARY NETWORK

Station No.	Station Name	Latitude (North)	Longitude (East)	Height
6001	Thule, Greenland	76°32'	291°14'	77m
6002	Beltsville, Maryland	39 02	283 10	42
6003	Moses Lake, Washington	47 11	240 40	367
6004	Shemya, Alaska	52 43	174 07	30
6006	Tromso, Norway	69 38	19 00	150
6007	Lazes Air Force Base, Azores	37 45	334 25	55
6008	Paramaribo, Surinam	05 47	304 49	96
6011	Maui, Hawaii	20 43	203 44	3000
6012	Wake Island	19 16	166 39	5
6013	Kogoshima, Kyushu, Japan	31 30	130 27	500
6014	Tinsukia, India	27 29	95 21	120
6015	Mashhad, Iran	36 15	59 35	1200
6016	Palermo, Sicily	38 09	13 20	104
6017	Roberts Field, Liberia	06 15	349 40	8
6018	Trinidad Island	-20 30	330 40	100
6019	Villa Dolores, Argentina	-31 57	294 54	545
6020	Easter Island	-27 09	250 35	30
6022	Pago Pago, American Samoa	-14 20	189 18	2
6023	Cape York, Australia	-12 47	143 18	50
6027	Springbok, South Africa	-29 42	17 57	821
6028	Saunders Island, S.S.I.	-57 48	333 32	100
6031	Queenstown, New Zealand	-45 02	168 43	366
6032	Perth, Australia	-31 06	115 58	111
6037	Galapagos Island	-00 58	269 00	50
6038	Revilla Gigedo Islands	18 50	249 00	50
6039	Oeno Island	-23 55	229 15	50
6040	Cocos (or Keeling) Island	-22 11	96 50	20
6041	Mangalore, India	12 58	74 54	150
6042	Addis Ababa, Ethiopia	09 00	38 44	2362
6043	Punta Arenas, Chile	-53 10	289 06	100
6044	Heard Island	-53 08	73 42	50
6045	Mauritius, Mascarene Island	-20 25	57 40	50
6047	Zamboanga, Philippines	06 56	122 04	10
6048	Caroline Island	-09 58	209 47	10
6049	Bata, Rio Muni	01 50	09 47	100

TABLE 3 (continued)

Station No.	Station Name	Latitude (North)	Longitude (East)	Height
6050	Palmer Station, Antarctica	-64°40'	259° 37'	
6051	Mawson Station, Antarctica	-67 36	63 00	
6052	Wilkes Station, Antarctica	-66 15	110 38	
6053	McMurdo Sound, Antarctica	-77 57	166 40	
6054	Amundsen Scott Station, Ant.	-90 00		
6056	Sal, Cape Verde Islands	16 40	337 06	

TABLE 4
USCGS-DOD SECONDARY NETWORK

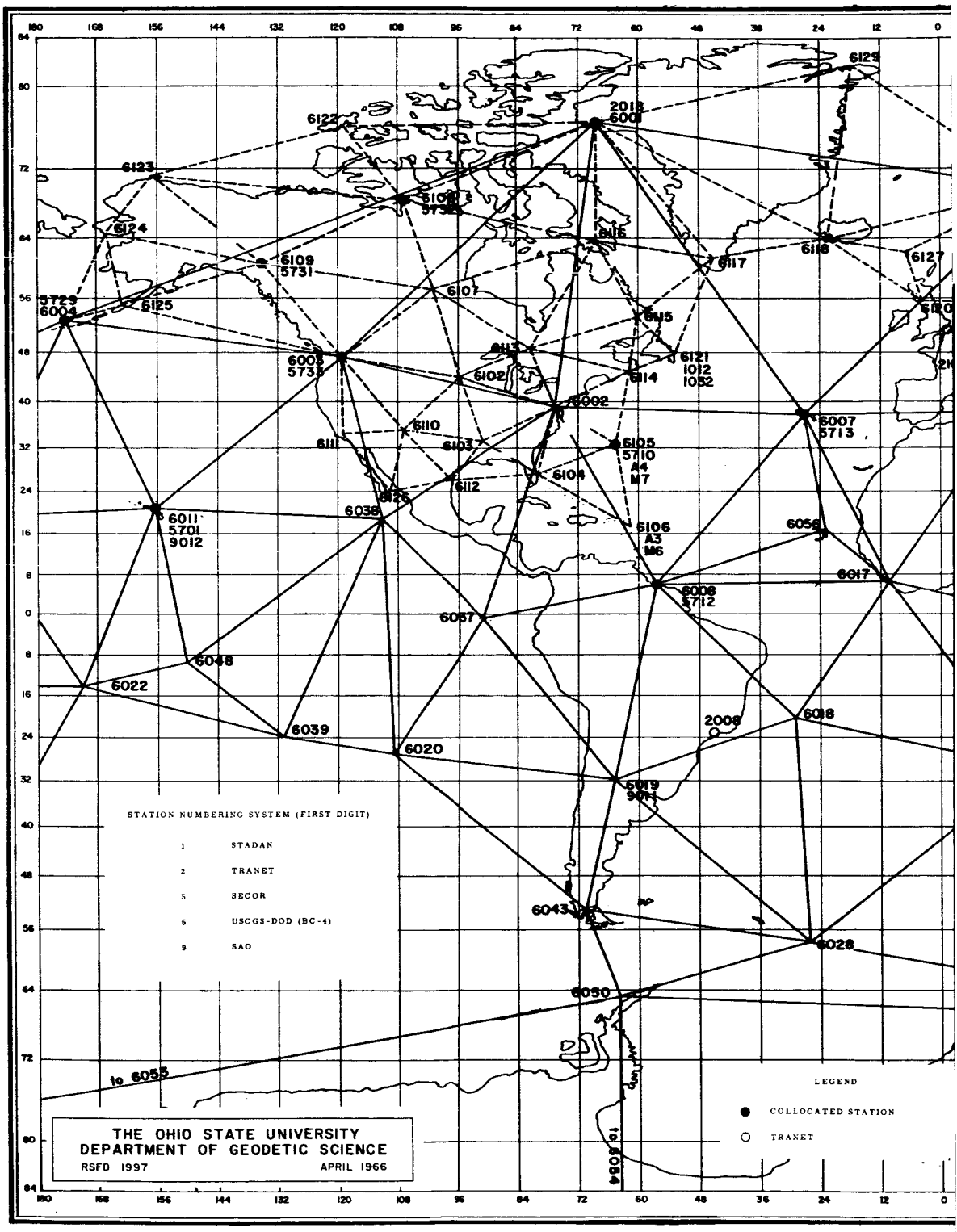
Station No.	Station Name	Latitude (North)	Longitude (East)	Height
6102	Chandler, Minnesota	43°53'	264°04'	560m
6103	Greenville, Mississippi	33 29	269 00	42
6104	Valkaria, Florida	27 57	279 27	9
6105	Bermuda Island	32 22	295 20	20
6106	Antigua, B.W.I.	17 08	298 13	6
6107	Lynn Lake, Manitoba	56 52	258 57	352
6108	Cambridge Bay, N.W.T.	69 07	254 56	15
6109	Whitehorse, Y.T.	60 44	224 55	723
6110	Albuquerque, New Mexico	34 57	253 32	1833
6111	Wrightwood, California	34 23	242 19	2282
6112	Brownsville, Texas	26 00	262 35	5
6113	Timmins, Ontario	48 34	278 38	291
6114	Halifax, Nova Scotia	44 38	296 30	50
6115	Goose Bay, Labrador	53 19	299 38	35
6116	Frobisher Bay, Baffin Island	63 46	291 27	35
6117	Nanartalik, Greenland	61 09	45 27	6
6118	Keflavik, Iceland	63 58	314 33	40
6120	Edinburgh, Scotland	55 40	3 14	282
6121	St. John's, Newfoundland	47 38	307 16	150
6122	Mould Bay, N.W.T.	76 10	240 25	13
6123	Pt. Barrow, Alaska	71 19	203 21	9
6124	Nome, Alaska	64 30	194 40	34
6125	Cold Bay, Alaska	55 12	197 17	30
6126	La Paz, Mexico	23 30	250 00	
6127	Torshaven, Faeroe Islands	62 00	353 15	
6129	Nord, Greenland	81 36	343 20	35
6132	Copenhagen, Denmark	55 44	12 30	51
6200	Tabriz, Iran			
6201	Amman, Jordan			
6203	Zahedan, Iran			
6204	Bahrain, Saudi Arabia			
6205	Port Sudan, Sudan			
6206	Aden, South Arabia			
6207	Salalah, Saudi Arabia			

TABLE 5
STATIONS COLLOCATED WITH THE USCGS-DOD NETWORK

Station Name	USCGS[1] Stations	SAO[2] Stations	SECOR[3] Stations	TRANET[4] Stations	NASA Supported[5] Stations
Thule, Greenland	6001			2018	
Moses Lake, Wash.	6003		5733		
Shemya, Alaska	6004		5729		
Lazes Air Force Base, Azores	6007		5713		
Paramaribo, Surinam	6008		5712		
Maui, Hawaii	6011	9102	5701		
Wake Island	6012		5728		
Tinsukia, India	6014		5722		
Addis Ababa, Ethiopia	6042		9028		
Zamboanga, Philippines	6047		5725		
McMurdo Sound, Antarctica	6053			2019	
Bermuda Island	6105		5710		A4, M7
Cambridge Bay, Canada	6108		5732		
Whitehorse, Canada	6109		5731		
Antigua	6106				A3, M6
St John's, Newfoundland	6121				1032, 1012
Villa Dolores, Argentina	6019	9011			
Amman, Jordan	6201		5718		
Aden, South Arabia	6206		5719		

[1] See Tables 3 and 4
[2] See Table 6
[3] See Table 11
[4] See Table 9
[5] See Table 6

USCGS-DOD, BC-4 NETWORK WITH COL



Figure

LOCATED AND ABSOLUTE STATIONS

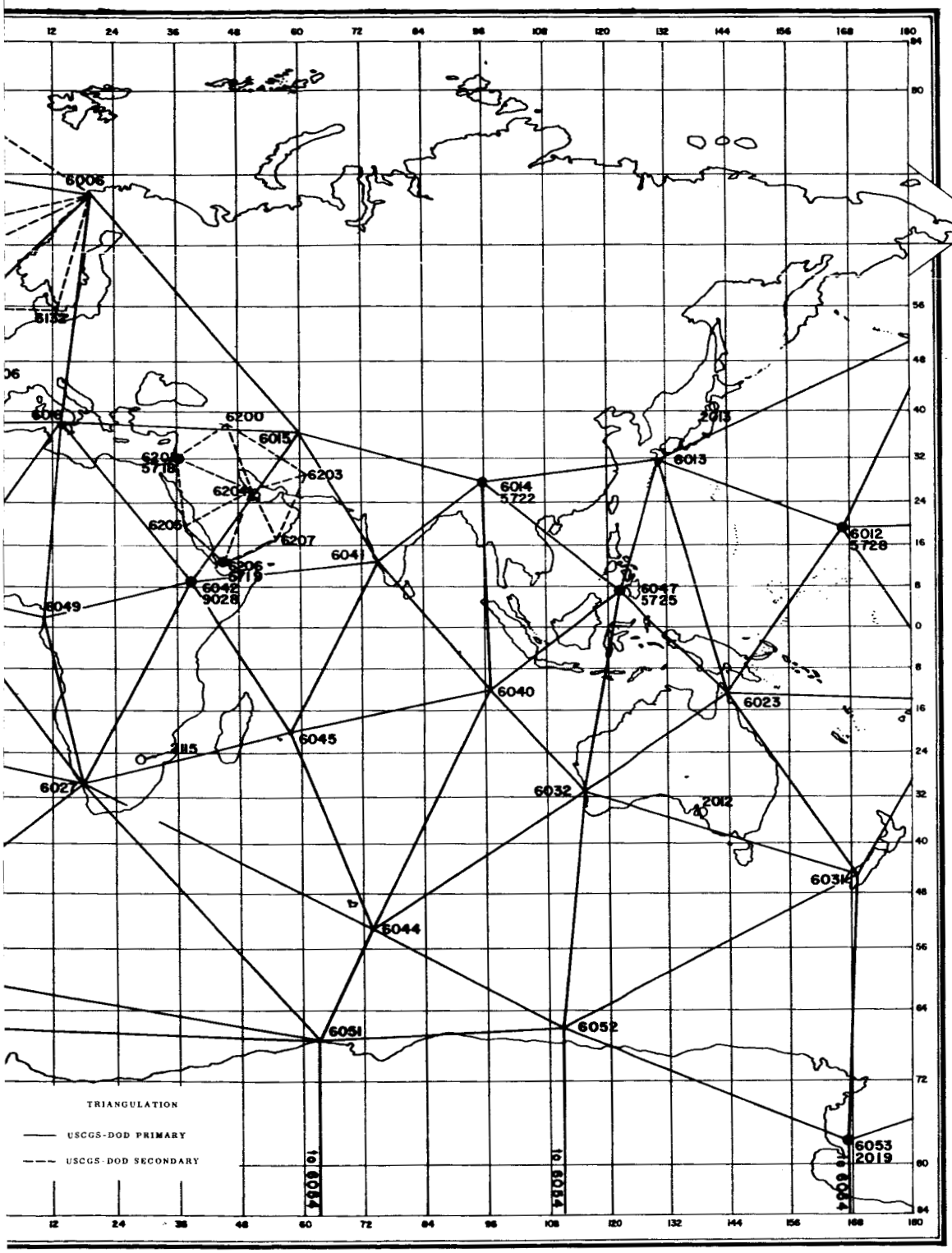


TABLE 6
NASA SUPPORTED NETWORK

Station Name	Latitude (North)	Longitude (East)	Height	Manned Space Flight Network	Apollo Unified S-Band Network	Satellite Tracking and Data Acquisition Network		Smithsonian Optical Tracking Network	Deep Space Instrumentation Facilities	Range and Range Rate Facilities
						MINI-TRACK	MOTS			
Patrick Air Force Base	28° 14'	279°24'	15m	M1						
Cape Kennedy	28 29	279 25	14	M2	A1					
Grand Bahama	26 37	281 39	14	M3	A2					
San Salvador	24 07	285 30	3	M4						
Grand Turk	21 28	288 52	25	M5	A15					
Antigua	17 09	298 12	26	M6	A3					
Bermuda Island	32 21	295 21	3	M7	A4					
Canary Islands	27 44	344 24	29	M8	A6					
Ascension Island	-07 58	345 36	143	M9	A5					
Carnarvon, Australia	-24 54	113 43	64	M10	A8					1152
Woomera, Australia	-30 49	136 50	151	M12		1018	1024	9023		
Kauai, Hawaii	22 08	200 20	1142	M13	A11					
Point Arguello	34 35	239 26	646	M14						
Guaymas, Mexico	27 58	249 17	18	M15	A13					
White Sands, New Mexico	32 21	253 38	232	M16						

TABLE 6 (continued)

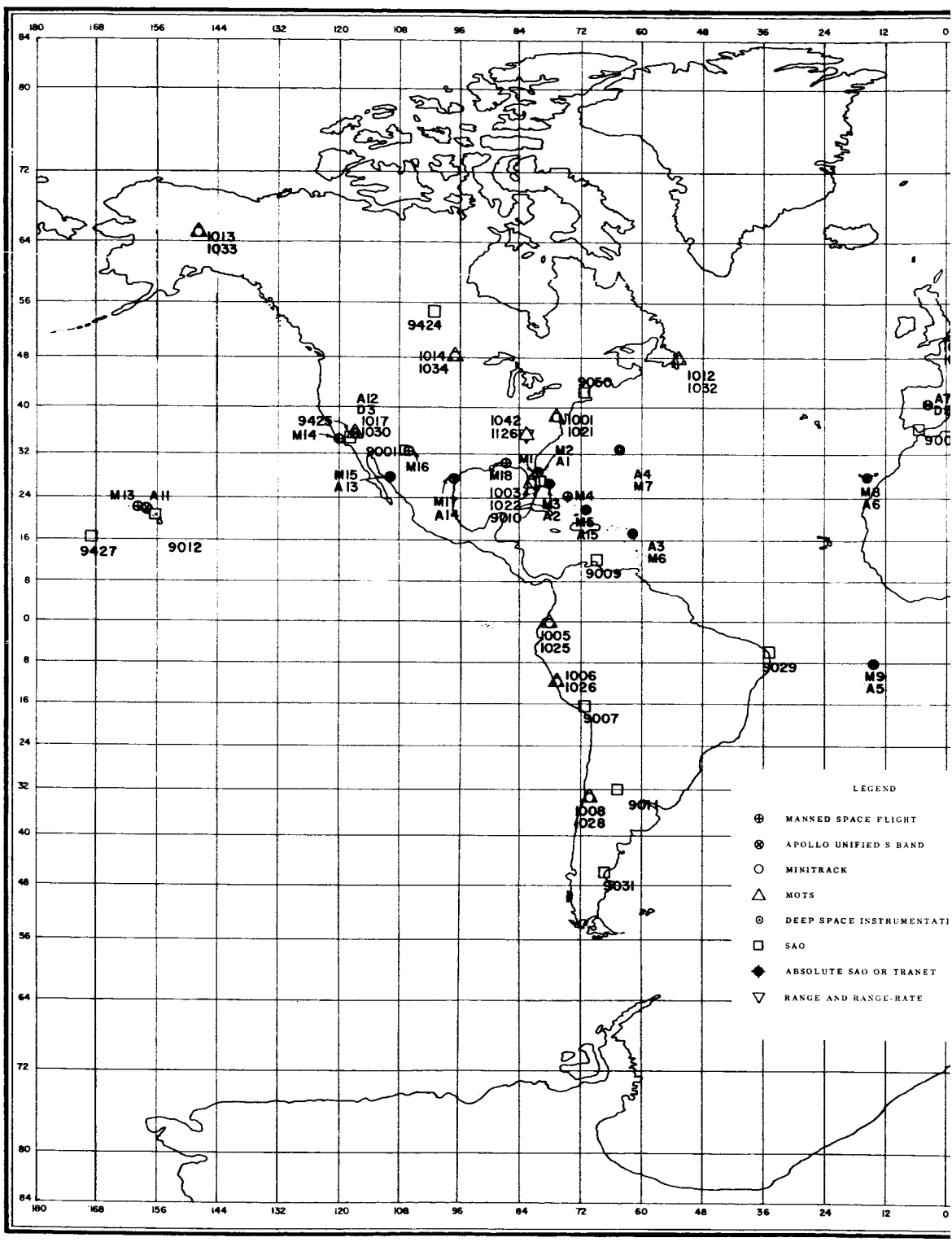
Station Name	Latitude (North)	Longitude (East)	Height	Manned Space Flight Network	Apollo Unified S-Band Network	Satellite Tracking and Data Acquisition Network		Smithsonian Optical Tracking Network	Deep Space Instrumentation Facilities	Range and Range Rate Facilities
						MINI-TRACK	MOTS			
Corpus Christi	27°39'	262°37'	10m	M17	A14					
Elgin Air Force Base	30 25	273°12	28	M18						
Canberra, Australia	-35 36	148 59	1097		A9					
Guam	13 19	144 44	86		A10					
Goldstone, California	35 20	243 08	960		A12				D3	
Rosman, North Carolina	35 12	277 08	908				1042			1126
Madrid, Spain	40 27	355 50	722		A7				D5	
Pretoria, R. S. A.	-25 57	28 21	1584		A17					
E. Grand Forks, Minnesota	48 01	262 59	250			1014	1034			
Fort Meyers, Florida	26 33	278 08	9			1003	1022			
Blossom Point, Maryland	38 26	282 55	6			1001	1021			
St. John's, Newfoundland	47 44	307 17	112			1012	1032			

TABLE 6 (continued)

Station Name	Latitude (North)	Longitude (East)	Height	Manned Space Flight Network	Apollo Unified S-Band Network	Satellite Tracking and Data Acquisition Network		Smithsonian Optical Tracking Network	Deep Space Instrumentation Facilities	Range and Range Rate Facilities
						MINI-TRACK	MOTS			
Quito, Ecuador	-00°37'	281°25'	3578m			1005	1025			
Lima, Peru	-11 47	282 51	34			1006	1026			
Santiago, Chile	-33 09	289 20	681			1008	1028			
Winkfield, Eng.	51 27	359 18	88			1015	1035			
Johannesburg, R. S. A.	-25 53	27 42	1565			1016	1031		D2	
College, Alaska	64 52	212 10	189			1013	1033			
Tananarive, Madagascar	-19 01	47 18	1392							1122
Organ Pass, New Mexico	32 25	253 27	1650					9001		
Olifantsfontein, R. S. A.	-25 58	28 15	1586					9002		
San Fernando, Spain	36 28	353 48	68					9004		
Tokyo, Japan	35 40	139 32	109					9005		
Naini Tal, India	29 22	79 27	1924					9006		
Arequipa, Peru	-16 28	288 30	2457					9007		
Shiraz, Iran	29 38	52 31	1631					9008		
Curacao, N. W. I.	12 05	291 10	5					9009		
Jupiter, Florida	27 01	279 53	15					9010		

TABLE 6 (continued)

Station Name	Latitude (North)	Longitude (East)	Height	Manned Space Flight Network	Apollo Unified S-Band Network	Satellite Tracking and Data Acquisition Network		Smithsonian Optical Tracking Network	Deep Space Instrumentation Facilities	Range and Range Rate Facilities
						MINI-TRACK	MOTS			
Villa Dolores, Argentina	-31°57'	294°54'	598m					9011		
Maui, Hawaii	20 43	203 44	3021					9012		
Natal, Brazil	-05 56	324 50	42					9029		
Comod. Rivid., Argentina	-45 55	292 29	200					9031		
Debra Zeit, Ethiopia	08 45	38 58	1921					9028		
Cold Lake, Canada	54 45	249 57	600					9424		
Edwards A. F. B., California	34 58	242 05	0					9425		
Oslo, Norway	60 13	10 45	585					9426		
Johnston Island	16 45	190 29	5					9427		
Athens, Greece	37 58	23 48	186					9051		
Agassiz	42 30	288 26	184					9050		


1013
1033
9424
1014
1034
1012
1032
9050
A12
D3
1017
1030
9425
M14
1042
1126
1001
1021
M2
A1
9001
M16
M1
M18
M15
A13
A4
M7
M13
A11
1003
1022
9010
M17
A14
M3
A2
M4
M5
A15
A3
M6
9427
9012
9009
M8
A6
1005
1025
9029
M9
A5
1006
1026
9007
1008
1028
9011
9031
LEGEND
MANNED SPACE FLIGHT
APOLLO UNIFIED S BAND
MINITRACK
MOTS
DEEP SPACE INSTRUMENTATI
SAO
ABSOLUTE SAO OR TRANET
RANGE AND RANGE-RATE

Figure

5-1

ED STATIONS

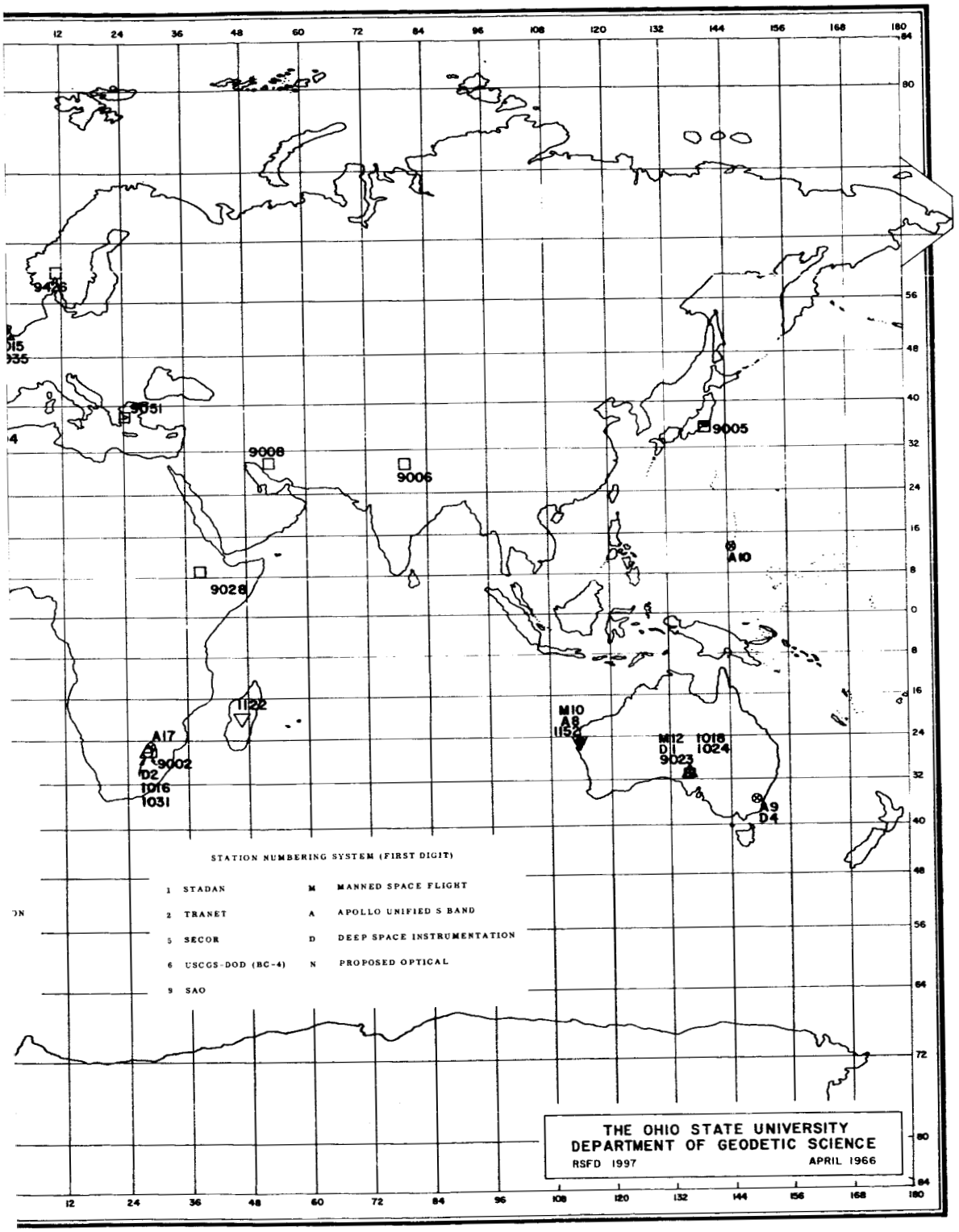

STATION NUMBERING SYSTEM (FIRST DIGIT)
1 STADAN
2 TRANET
5 SECOR
6 USCGS-DOD (BC-4)
9 SAO
M MANNED SPACE FLIGHT
A APOLLO UNIFIED S BAND
D DEEP SPACE INSTRUMENTATION
N PROPOSED OPTICAL
9426
9051
9008
9006
9005
9028
A10
1122
M10
A8
1152
A17
9002
D2
1016
1031
M12
D1
9023
1018
1024
A9
D4
THE OHIO STATE UNIVERSITY
DEPARTMENT OF GEODETIC SCIENCE
RSFD 1997
APRIL 1966

TABLE 7
PROPOSED OPTICAL NETWORK
(Supplementary to the USCGS-DOD Network)

OSU NO.	LOCATION	CAMERA TYPE		TO OBSERVE SIMULTANEOUSLY WITH NETWORK				COLLOCATED STATIONS									
		MOTS, BAKER-NUNN	BC-4	USCGS-DOD	BAKER-NUNN	MOTS	OSU	USCGS	STADAN		TRANET	SECOR	SAO	MANNED SPACE FLIGHT	APOLLO	DEEP SPACE	RANGE AND RANGE RATE
									MINITRACK	MOTS							
N 1(6)	Cold Lake, Can.		x	6003 6001 6002									9424				
N 2(6)	Oslo, Norway		x	6006 6007 6016									9426				
N 3(6)	Winkfield, Eng.		x	6006 6007 6016					1015	1035	2106						
N 4(6)	Misawa, Japan		x	6023 6012 6004							2013						
N 5(6)	Tokyo, Japan		x	6023 6012 6004									9005				

TABLE 7 (continued)

OSU NO.	LOCATION	CAMERA TYPE		TO OBSERVE SIMULTANEOUSLY WITH NETWORK				COLLOCATED STATIONS									
		MOTS, BAKER-NUNN	BC-4	USCGS-DOD	BAKER-NUNN	MOTS	OSU	USCGS	STADAN: MINITRACK	STADAN: MOTS	TRANET	SECOR	SAO	MANNED SPACE FLIGHT	APOLLO	DEEP SPACE	RANGE AND RANGE RATE
N 6(1)	Madrid, Spain	x			9004	1035	N11								A7	D5	
N 7(6)	Adelaide, Australia		x	6023 6031 6032							2012						
N 8(6)	Canary Islands		x	6007 6016 6056										M8	A6		
N 9(6)	Ascension Island		x	6018 6017 6027										M9	A5		
N 10(6)	Sao Jose dos Campos, Brazil		x	6018 6019 6008							2008						

TABLE 7 (continued)

OSU NO.	LOCATION	CAMERA TYPE		TO OBSERVE SIMULTANEOUSLY WITH NETWORK				COLLOCATED STATIONS									
									STADAN								
		MOTS, BAKER-NUNN	BC-4	USCGS-DOD	BAKER-NUNN	MOTS	OSU	USCGS	MINITRACK	MOTS	TRANET	SECOR	SAO	MANNED SPACE FLIGHT	APOLLO	DEEP SPACE	RANGE AND RANGE RATE
N 11(1)	Palermo, Sicily	x					N6	6016									
N 12(1)	Bata, Rio Muni	x					N13 N16 N33	6049									
N 13(1)	Sao Tome	x					N12 N14 N16										
N 14(1)	Angola	x				1031	N13 N15 N16										
N 15(1)	Springbok, South Africa	x				1031	N14	6027									
N 16(1)	Rwanda	x			9028 9002	1031	N12 N13 N14 N17 N33										

TABLE 7 (continued)

OSU NO.	LOCATION	CAMERA TYPE		TO OBSERVE SIMULTANEOUSLY WITH NETWORK				COLLOCATED STATIONS									
		MOTS, BAKER-NUNN	BC-4	USCGS-DOD	BAKER-NUNN	MOTS	OSU	USCGS	STADAN: MINTRACK	STADAN: MOTS	TRANET	SECOR	SAO	MANNED SPACE FLIGHT	APOLLO	DEEP SPACE	RANGE AND RANGE RATE
N 17(1)	Tanzania	x			9028 9002	1031	N16 N18										
N 18(1)	Tananarive, Madagascar	x			9002	1031	N17 N19										1122
N 19(1)	Mauritius Mascarene Is.	x					N18	6045									
N 20(6)	Guam		x	6013 6012 6023											A10		
N 21(1)	Zamboanga,	x					N22 N23 N25 N34	6047				5725					

TABLE 7 (continued)

OSU NO.	LOCATION	CAMERA TYPE		TO OBSERVE SIMULTANEOUSLY WITH STATIONS				COLLOCATED STATIONS									
		MOTS, BAKER-NUNN	BC-4	USCGS-DOD	BAKER-NUNN	MOTS	OSU	USCGS	STADAN: MINITRACK	STADAN: MOTS	TRANET	SECOR	SAO	MANNED SPACE FLIGHT	APOLLO	DEEP SPACE	RANGE AND RANGE RATE
N 22(1)	Sumatra	x					N34 N21 N23 N24 N25										
N 23(1)	Celebes	x					N26 N34 N21 N22 N25										
N 24(1)	Cocos (or Keeling)						N22 N25 N27	6040									

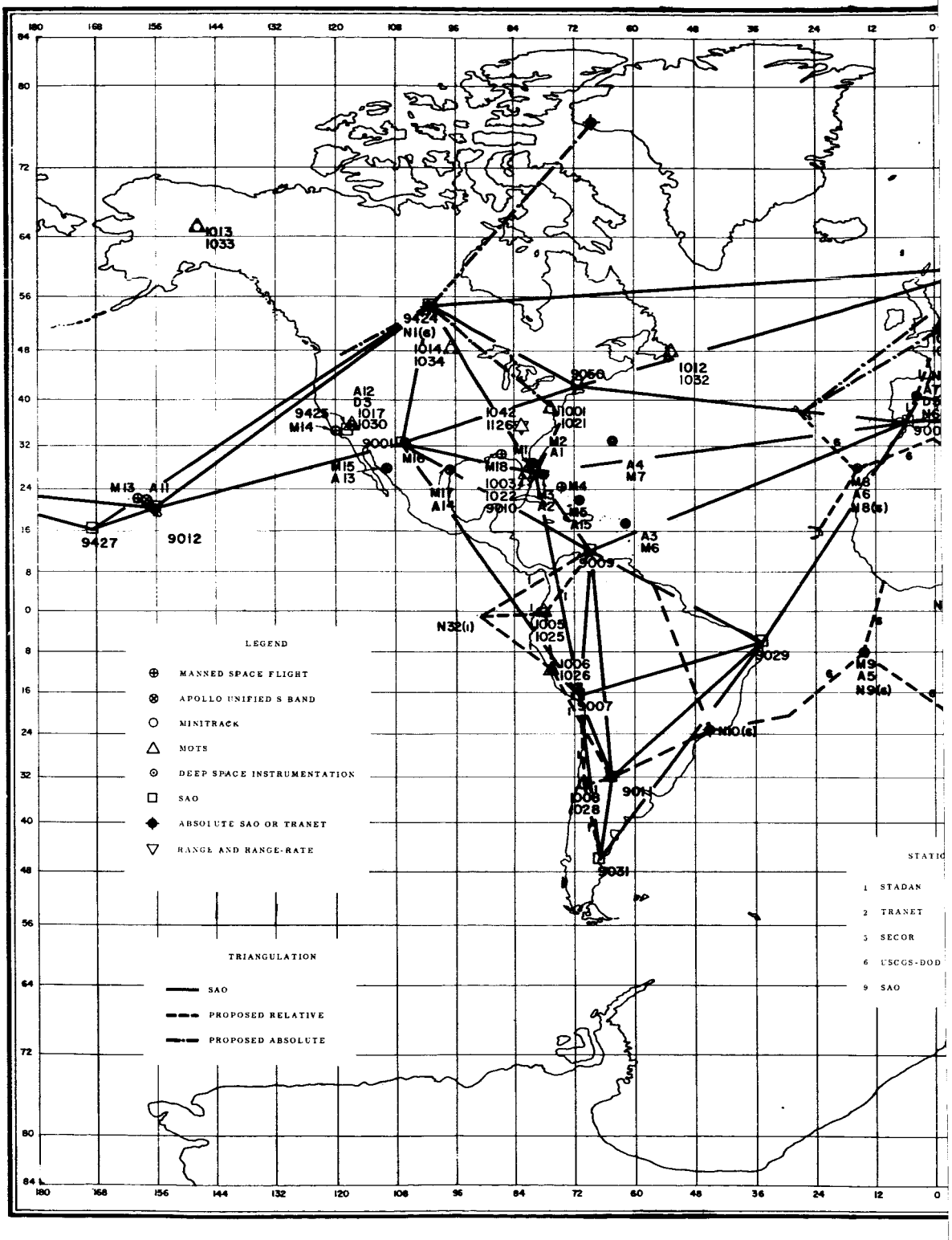
TABLE 7 (continued)

OSU. NO.	LOCATION	CAMERA TYPE		TO OBSERVE SIMULTANEOUSLY WITH STATIONS				COLLOCATED STATIONS									
		MOTS, BAKER-NUNN	BC-4	USCGS-DOD	BAKER-NUNN	MOTS	OSU	USCGS	STADAN: MINITRACK	STADAN: MOTS	TRANET	SECOR	SAO	MANNED SPACE FLIGHT	APOLLO	DEEP SPACE	RANGE AND RANGE RATE
N 25(1)	Java	x					N24 N21 N27 N34 N22 N23 N26										
N 26(1)	Australia	x			9023	1024	N23 N29 N25 N27										
N 27(1)	Carnarvon, Australia	x			9023	1024	N24 N25 N26							M10	A8		
N 28(1)	Canberra, Australia	x			9023	1024	N30 N29								A9	D4	

TABLE 7 (continued)

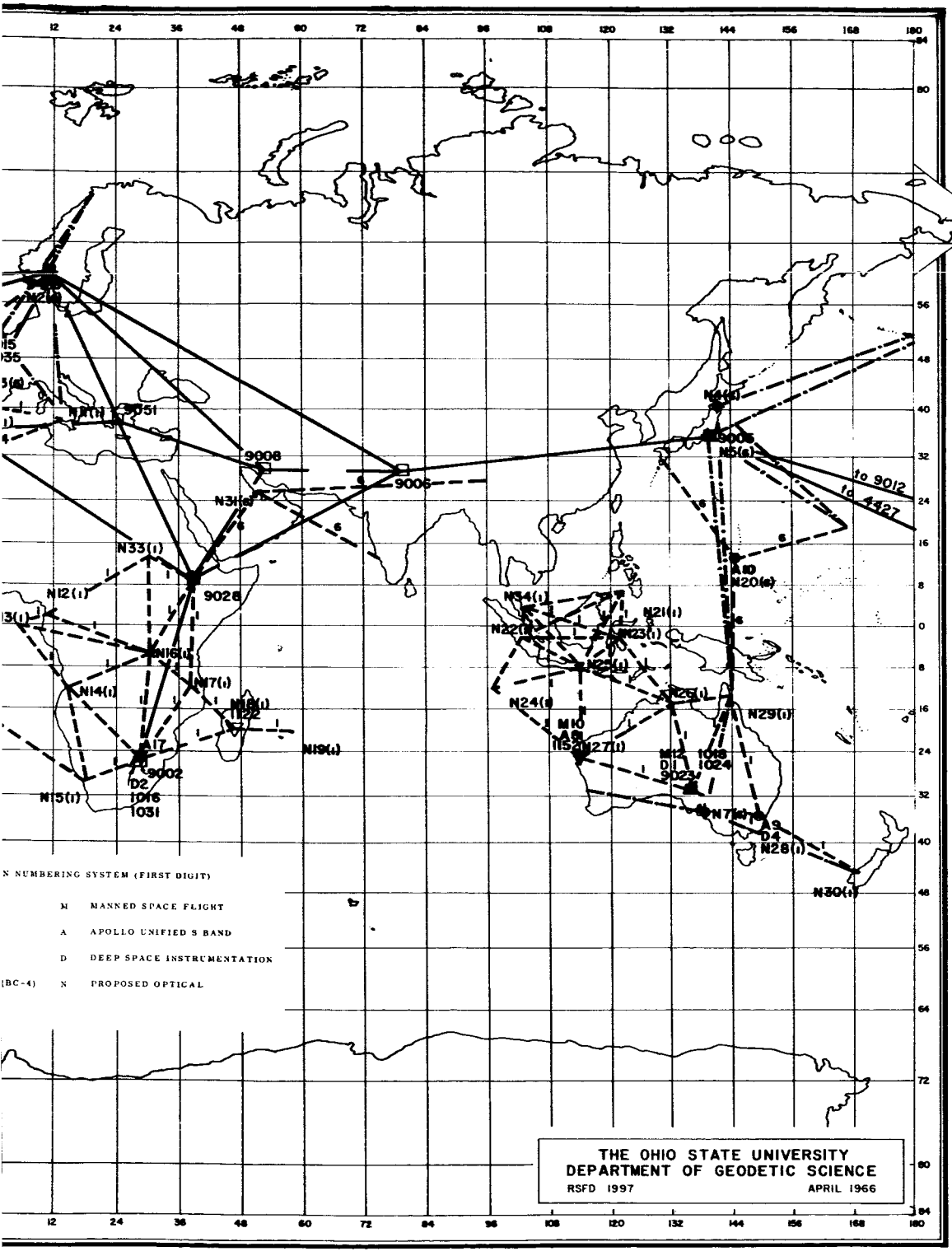
OSU NO.	LOCATION	CAMERA TYPE		TO OBSERVE SIMULTANEOUSLY WITH STATIONS				COLLOCATED STATIONS									
		MOTS, BAKER-NUNN	BC-4	USCGS-DOD	BAKER-NUNN	MOTS	OSU	USCGS	STADAN: MINITRACK	STADAN: MOTS	TRANET	SECOR	SAO	MANNED SPACE FLIGHT	APOLLO	DEEP SPACE	RANGE AND RANGE RATE
N 29(1)	Cape York, Australia	x			9023	1024	N26	6023									
N 30(1)	Queenstown, New Zealand	x					N28	6031									
N31 (6)	Bahrain, Saudi Arabia		x	6014 6041 6042				6204									
N 32(1)	Galapagos Islands	x			9009	1025 1026		6037									
N 33(1)	Sudan	x			9028		N12 N16										
N 34(1)	Malaya	x					N22 N21 N23 N25										

PROPOSED OPT



Figure

ICAL NETWORK



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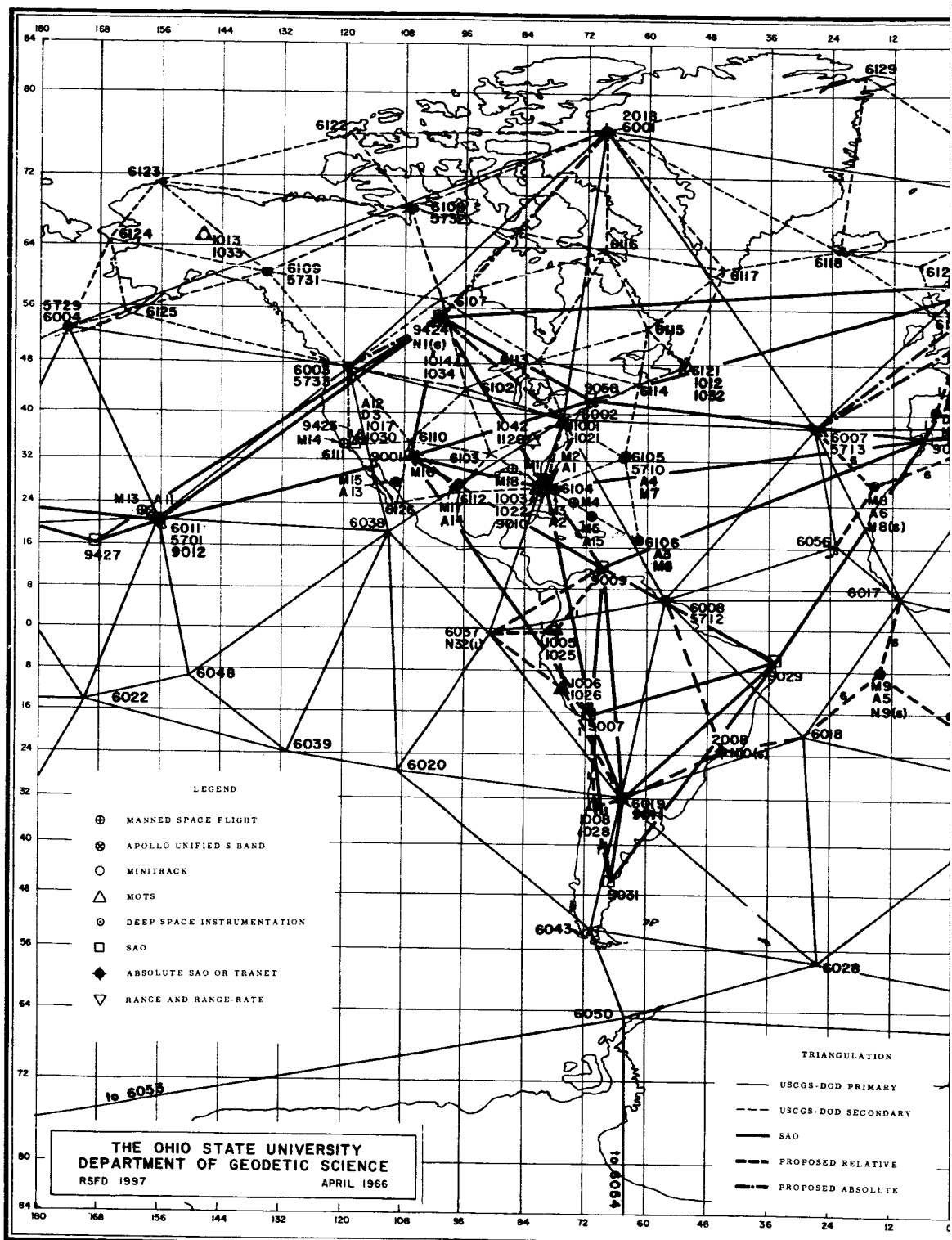

Figur

TICAL NETWORK

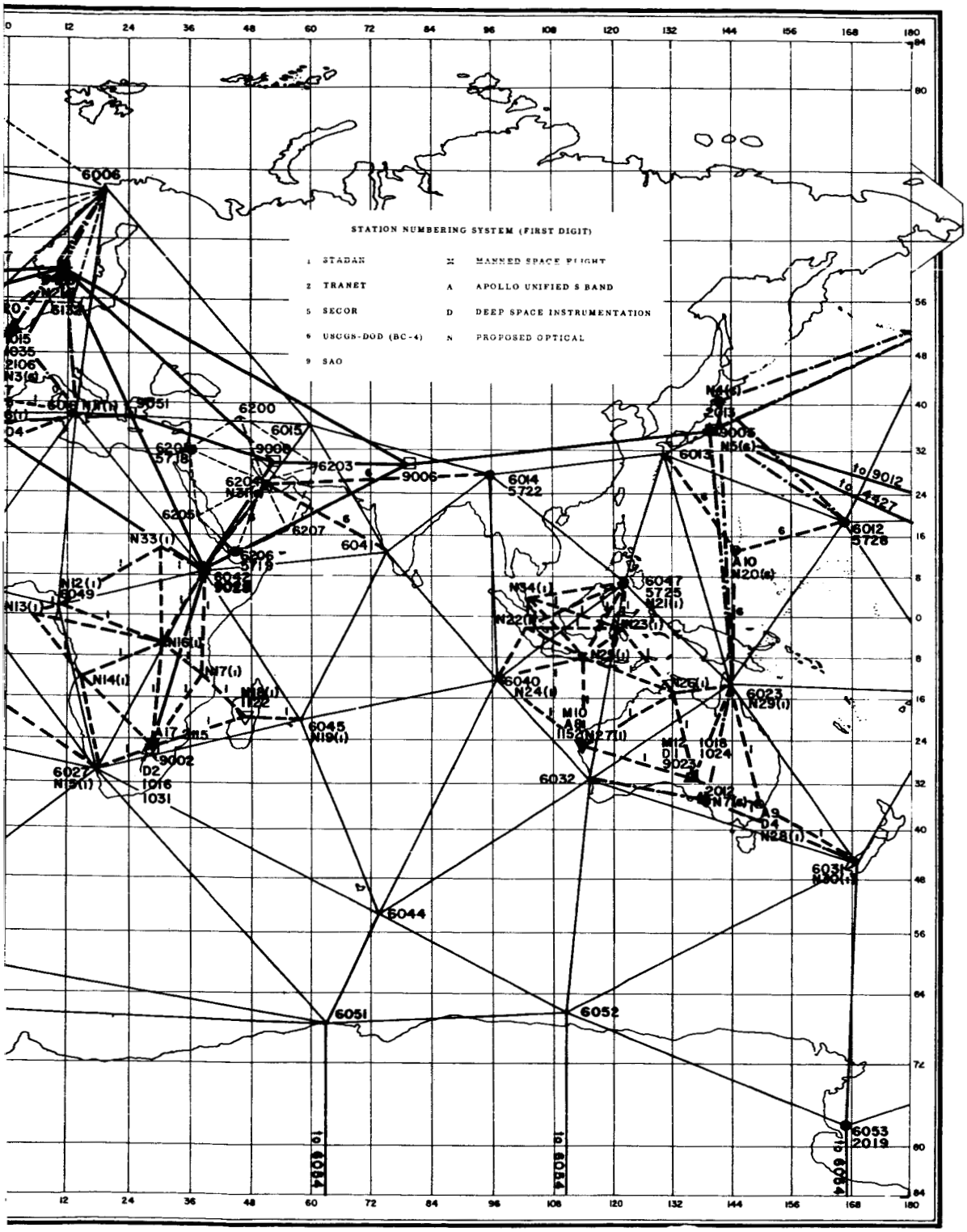

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TABLE 8
APPROXIMATE OBSERVATIONAL REQUIREMENTS

	Network	Observational Requirements
Absolute Stations	SAO	Data from six stations indicated in Figure 6 for approximately two years of observations on satellites of various inclinations or absolute coordinates.
	TRANET	Data from six stations indicated in Figure 6 at intervals of 20 to 60 seconds for approximately three to four months per satellites of various inclinations, or absolute coordinates.
Relative Stations	Type (6) optical stations observing passive satellites with cameras equipped with trail-choppers (e.g., BC-4)	Three to seven simultaneous observations between stations.
	Type (1) optical stations observing flashes or single satellite images (e.g., PC 1000, or Baker Nunn)	Twenty-five to fifty simultaneous observations between stations.
	SECOR	Selected aggregated data from twenty five to forty passes per observing group of four stations each.

APPENDIX

DOD Observational Plan
(Supplementary to USCGS-DOD Plan)

TABLE 9
DOD PERMANENT TRANET NETWORK

Station No.	Station Name	Latitude (North)	Longitude (East)	Height
2008	Sao Jose dos Campos, Brazil	-23° 13'	314°07'	608m
2011	San Miguel, Philippines	14 59	120 04	8m
2012	Adelaide, Australia	-34 40	138 38	23
2013	Misawa, Japan	40 43	141 20	12
2014	Anchorage, Alaska	61 17	210 17	66
2017	Tafuna, American Samoa	-14 20	189 17	6
2018	Thule, Greenland	76 32	291 14	24
2019	McMurdo Sound, Antarctica	-77 57	166 40	30
2100	Wahiwa	21 31	202 00	388
2103	Las Cruces, New Mexico	32 17	253 15	1203
2106	Lasham, England	51 11	358 58	190
2111	Scaggsville, Maryland	39 10	283 06	145
2115	Pretoria, South Africa	-25 57	28 21	1580
2717	Mahe Seychelles	-04 40	55 29	596

TABLE 10
DOD TRANET-VAN NETWORK

Station No.	Station Name
	1966
266-1	Athens, Greece
266-2	Auckland, New Zealand
266-3	Canary Islands
266-4	Chesterfield, Canada
266-5	Fiji Islands
266-6	Hamilton, Canada
266-7	Kagoshima, Japan
266-8	Lazes Air Force Base, Azores
266-9	Lisbon, Portugal
266-10	Madeira
266-11	Mashhad, Iran
266-12	Narssarssuaq, Greenland
266-13	Palermo, Sicily
266-14	Queenstown, New Zealand
266-15	Rota, Spain
266-16	Scoresbysund, Greenland
266-17	Tuktoyaktuk, N.W.T. Canada
266-18	Upernavik, Greenland
	1967
267-1	Arequipa, Peru
267-2	Cape Verde Islands
267-3	Chagos Archipelago
267-4	Curacao, N.W.I.
267-5	Easter Island
267-6	Gilbert Islands
267-7	Karachi, Pakistan
267-8	Keflavik, Iceland
267-9	Manheim, Madras, India
267-10	Oslo, Norway
267-11	Paramaribo, Surinam
267-12	Punta Arenas, Chile
267-13	Rio Cuarto, Argentina
267-14	Roberts Field, Liberia
267-15	Saunders Island
267-16	Society Islands

TABLE 10 (continued)

Station No.	Station Name
	1967
267-17	Spitsbergen
267-18	Tinsukia, India
267-19	Trinidad Island
267-20	Tromso, Norway
267-21	Umea, Sweden
267-22	Villa Dolores, Argentina
267-23	Zamboanga, Philippines
	1968
268-1	Addis Ababa, Ethopia
268-2	Amundsen-Scott, Antarctica
268-3	Caroline Island
268-4	Galapagos Islands
268-5	Heard Island
268-6	Mangolore, India
268-7	Mauritius Mascarene Island
268-8	Mawson Station, Antarctica
268-9	Oeno Island
268-10	Palmer Station, Antarctica
268-11	Revilla Gigedo Island
268-12	Bata, Rio Muni
268-13	Springbok, South Africa
268-14	San Miguel, Azores
268-15	Wilkes Station, Antarctica

TABLE 11
DOD HIGH ALTITUDE SECOR NETWORK

Station No.	Station Name
5700	Midway
5701	Hilo, Hawaii
5702	Tarawa Island
5706	Grand Forks, North Dakota
5707	San Diego, California
5708	Savannah, Georgia
5710	Bermuda Island
5712	Paramaribo
5713	San Miguel, Azores
5715	Dakar, Senegal
5716	Tripoli, Libya
5717	El Fasher, Sudan
5718	Amman, Jordan
5719	Aden, South Arabia
5720	Jamnagar, India
5721	Diego Garcia, Chagos
5722	Tinsukia, India
5723	Singapore
5724	Hong Kong
5725	Zamboanga, Philippines
5726	Iwo Jima
5727	Manus Island
5728	Wake Island
5729	Fort Randall, Alaska
5730	Lagos, Nigeria
5731	White Horse, Canada
5732	Cambridge Bay, Canada
5733	Larson Air Force Base, Washington
5734	Panama, Canal Zone
5735	Natal, Brazil
5736	Ascension Island

TABLE 12
DOD PRESENT SECOR NETWORK

Western Pacific Network	Station Name
5-1	Urawa (Tokyo) Japan
5-2	Sasebo, Japan
5-3	Kobe, Japan
5-4	Okinawa
5-5	Minami Daito Shima
5-6	Iwo Jima
5-7	Minami Tori Shima (Marcus)
5-8	Guam
5-9	Yap Island
5-10	Truk Island
5-11	Woleai Atoll
5-13	Manus
5-14	Kwajakin Atoll
5-15	Kusau Island
5-16	Bauganville
5-17	Tarawa Atoll
5-18	Vanikoro Island
5-19	Rotuma
5-20	Howland Island
5-21	Pago Pago
5-22	Penrlyn
5-23	Palmyra Island
5-24	Johnston Island
5-25	Kauai, Hawaii
5-12	Eniwetok Atoll
U. S. Network	**Station Name**
5-26	E. Grand Forks, Minnesota
5-27	Fort Carson, Colorado
5-28	Stillwater, Oklahoma
5-29	Las Cruces, New Mexico
5-30	Austin, Texas
5-31	San Diego, California
5-32	Herndon, Virginia

TABLE 12 (continued)

U. S. Network	Station Name
5-33	Larson Air Force Base, Wash.
5-34	Greenville, Mississippi
5-35	Fort Stewart, Georgia
5-36	Homestead Air Force Base, Fla.

TABLE 13
DOD-PC 1000 OPTICAL NETWORK

Station No.	Station Name
3-1	Gottingen, Germany
3-2	Athens, Greece
3-3	Torrejon de Ardoz, Spain
3-4	Kanpur, India
3-5	Tokyo, Japan
3-6	Minot, North Dakota
3-7	Vandenberg A. F. B., California
3-8	Twin, Oklahoma
3-9	Bedford, Massachusetts
3-10	Colorado Springs, Colorado
3-11	Larson A. F. B., Washington
3-12	Fairbanks, Alaska
3-13	Santiago, Chile
3-14	Digarbakir, Turkey
3-15	Uppsala, Sweden
3-16	Capetown, South Africa
3-17	Tumalim, Luzon, Philippines
3-18	Cairns, Australia

ADDENDUM

Changes as of July 1, 1966 in the plans of the various organizations necessitate the following corrections in the preceding tables. (The diagrams were left unchanged).

Table	Reads	Should Read	Note
3	Lazes Air Force Base, Azores	Sao Miguel, Azores	
	Kagoshima Kyushu, Japan	Sasebo, Japan	
	Tinsukia, India	Mohanbari, India	
	Roberts Field, Liberia		delete
	Trinidad Island	Trindade Island	
	Cape York, Australia	Thursday, Australia	
	Saunders Island	South Georgia Island	
	Galapagos Island	Quito, Ecuador	
	Oeno Island	Pitcairn Island	
	Mangalore, India	Gan, Maldive Islands	
	Caroline Island	Christmas Island	
	Bata, Rio Muni	Santa Isabel, Fernando Foo	
	Sal, Cape Verde Island	Dakar, Senegal	
		6060 Culgooia, Australia	add
5	Tinsukia, India	Mohanbari, India	
11	Grand Forks, North Dakota	Chandler, Minnesota	
	Savannah, Georgia	Greenville, Mississippi	
	Jamnagar, India	Kandahar, India	
	Diego Garcia, Chagos	Gan, Maldive Islands	
	Tinsukia, India	Mohanbari, India	
	Cambridge Bay, Canada	Lynn Lake, Canada	
12	Urawa (Tokyo) Japan	Zama, Japan	
	Kwajakin Atoll		delete
	Kusau Island	Kusaie	
	Bauganville	Gizo (New Georgia)	
	Vanikoro Island	Swallow (Indiani)	

Table	Reads	Should Read	Note
12	Rotuma	Nandi	
	Howland Island	Canton	
	Penrlyn	Penrhyn	
	Kauai, Hawaii	Hilo, Hawaii	
	Eniwetak Atoll		delete
		Midway	add
		French Frigate Shoals	add
		5-37 Lynn Lake, Canada	add
		5-38 Chandler, Minnesota	add

Table 5

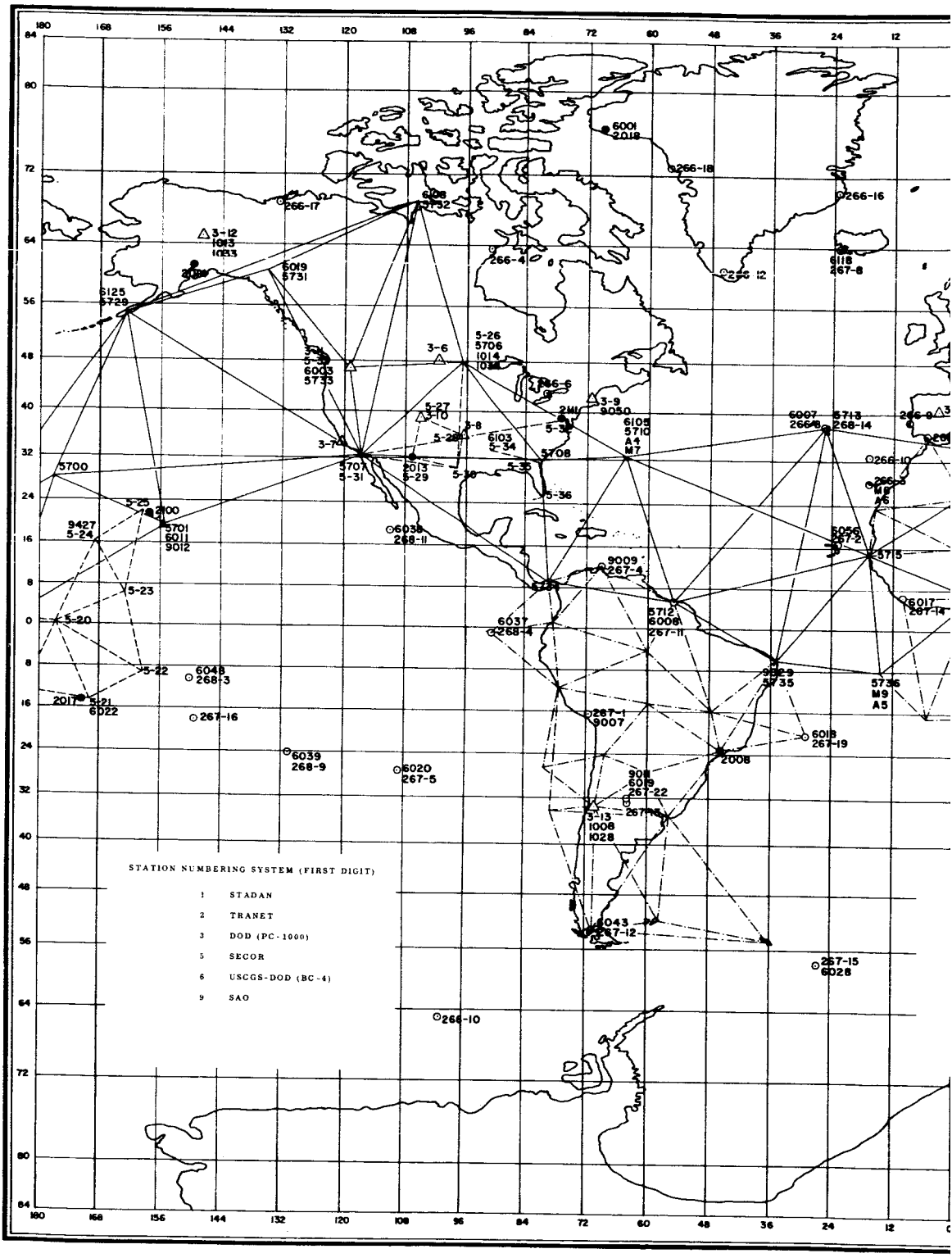
Station Name	USCGS[1] Stations	SECOR[3] Stations	Note
Dakar, Senegal	6056	5715	add
Gan, Maldive Islands	6041	5721	add
Lynn Lake, Canada	6107	5-37	add
Chandler, Minnesota	6102	5-38	add

[1] See Tables 3 and 4

[3] See Tables 11 and 12

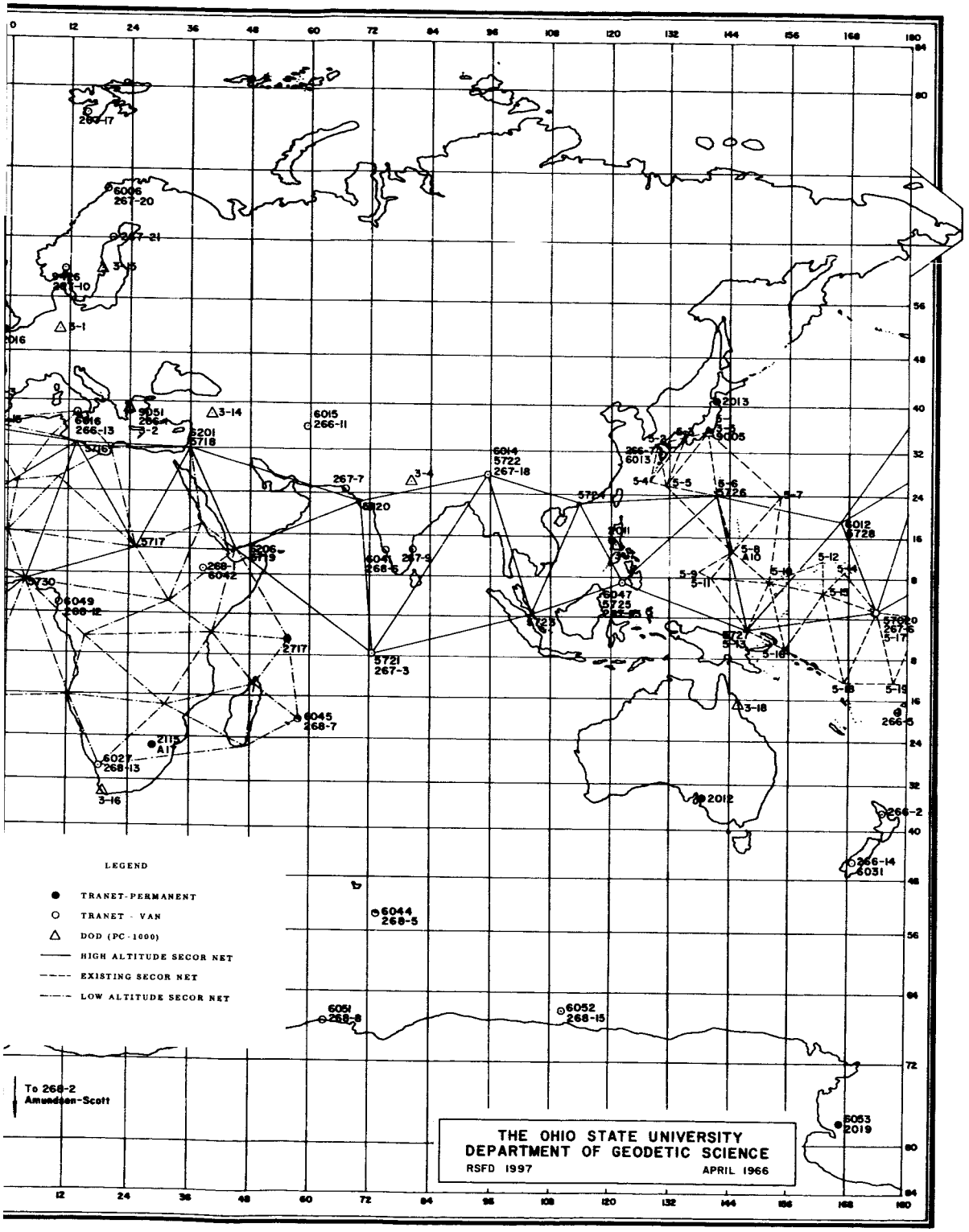
DOD OBSERVATION PLAN

(Complementary to USC



Figure

WITH COLLOCATED STATIONS
&GS-DOD network)



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For the Department of Geodetic Science

Project Supervisor Ivan I. Mueller Date 6.17, 1966

For The Ohio State University Research Foundation

Executive Director Robert C. Taylor Date 6/17, 1966

AS